Sehoul study site, Morocco

Highlights of work carried out in the DESIRE Project

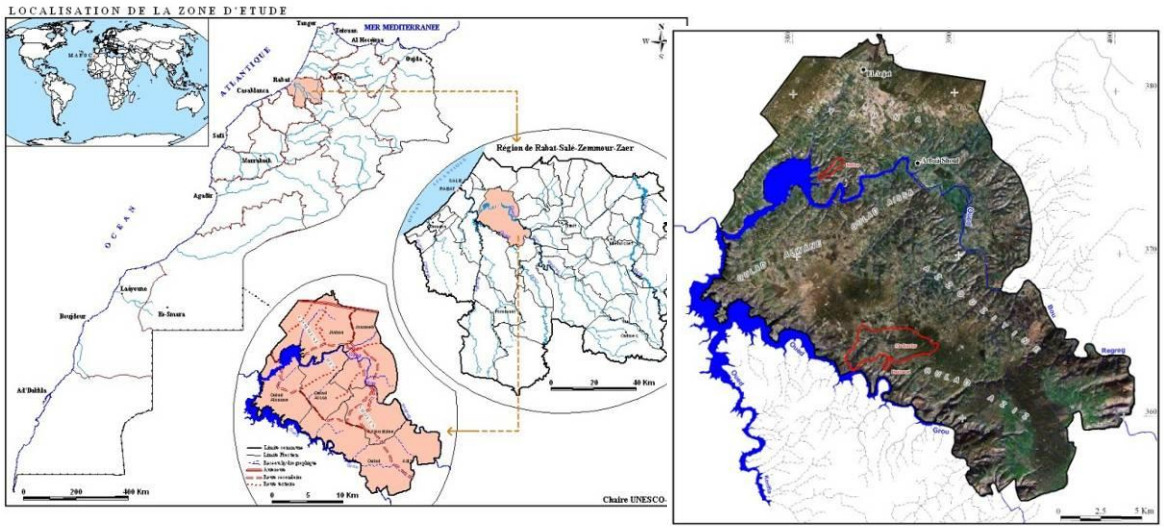
Based on work at Chaire UNESCO-GN "Gestion de l'Environnement et Développement Durable", Rabat

The study site

The Sehoul Plateau is located between the highway from Rabat to Fes in the north, and the Grou River in the south. It is a part of the old Atlantic Meseta.

- **Coordinates:**
  Latitude: 33°54' N
  Longitude: 6°38' W
- **Size:** 397 km²
- **Altitude:** 45 – 359 m
- **Precipitation:** 450 mm
- **Temperature:** na

- **Land use:** arable land, forest, shrubland
- **Inhabitants:** 19,706 (2004)
- **Main degradation processes:** water erosion
- **Major drivers of degradation:** inadequate land management, land use change, groundwater overexploitation



Study site location

In the Sehoul plateau, the traditional combination of agriculture, animal husbandry and forestry, with minimal human pressure, is now threatened by increasing pressures and the land use change. The degradation of the natural cork oak forest, the intensification of traditional land uses such as the reduction of fallow and the overgrazing on poor and fragile soils explain the high erosion rates and the trend to desertification. There is also increased competition for water between the natural vegetation, agriculture, urbanisation and tourism. Remediation strategies will include the experiments for cork oak forests regeneration, the production of fodder for livestock, and a range of rotation schemes for rainfed agriculture and fruit production.

The area considered, the Sehoul Plateau, is located between the highway from Rabat to Fes in the north, and the Grou river in the south. It is a part of the old Atlantic Meseta. The substrate consists of Paleozoic schists and sandstones, covered by Miocene molasse (limestone, calcarenite, pebbles) and marls, Pliocene calcarenite and old alluvial terraces consisting of pebbles, sands and clays.

Main reasons for selecting this site/region

In the semi-arid regions of Morocco, namely in the regions where WSC techniques are absent or rare, the vulnerability is very high. It incorporates three dimensions, a hydric dimension with the deeping of water table, an agrarian one with the decrease of yields, and an environmental one with the weakness of soils and the increase of erosion.

In these regions, there is a high risk of water scarcity and of an exacerbated competition between irrigation and water supply for the cities. The risk of natural catastrophes (floods, soil erosion) is also very high. The rapid urbanisation increases these risks, in relation with the land withdrawal, the water needs, the transformation of the sub-urban agriculture (extension of irrigation, choice for productions highly consuming water) and the implantation of new activities, as tourism.

In these regions, the ways of land management are often inadequate, with practices which accentuate the land vulnerability. The current transformations can exaggerate the hydric dynamics, namely runoff and erosion, because of the absence of techniques for water storage and water use during the cases of excessive rain.

The soils on the plateaus surface are very fragile. Nowadays the human pressure on the land and on the forest, produce conditions which lead to the removal of the superficial sand and the constitution of new dunes. The organic layer is rapidly destroyed during the dry years and the re-stabilization is very difficult to obtain. Only a good application of the adapted practices and a good management of the land can lead to a new equilibrium.

Climate

The daily intensities of rain are generally weak. Over 22 years (1970-2002), 794 days recorded more than 5 mm, which represents an average of only 26 days/year.

The frequency analysis of the monthly rains in the Rabat station shows that autumn is the more variable period, namely the months of November and December. This period is the most crucial for the hydrologic functioning of slopes and channels, because the fields are still bare. In 50% of the cases, we register total dryness; but the cases of intensive rain are numerous and have important effect. The last 3 decades show

a more important concentration of rain in autumn, with an average of intensity which reaches 20.4mm/rainy day. The other seasons don't show a real tendancy for change. During 32 years, 28 cases of intensive rains (>30mm) were recorded.

Vegetation cover

The forests are present north in the Mamora and in the central part of the Sehoul, south of the Bouregreg river

Existing practices on land and resource uses

This region originally covered by cork oak, is now cultivated and records a wide progress of irrigation with important change in the soil use and the cropping techniques. Rapid changes in land-use are occurring in these marginal areas originally used, before the 20th century, as natural areas for grazing or forestry. Current trends include replacement of evergreen oak forest by fast growing trees such as *Eucalyptus* species, and an increase in agriculture and grazing activities. The use of the good soils of the flat plateau for commercial crops in general pushed local poor communities to cultivate steep slopes, decreasing the forest and shrubland areas. In addition, an increasing number of sheep and goats, recorded in the 1960s and 1970s added pressure on natural resources. Therefore, areas traditionally occupied by sustainable forest and shrub land-uses are experiencing a change in intensification of land management practices, leading to the use of the poor lithosoils in an unsustainable way.

Many processes are observed: (i) Ploughing of steep slopes; (ii) Overgrazing of the shrubland areas, as a result of the increase of animals; (iii) Afforestation with exotic species.

The practices differ according to the type of land and resource. The cork oak forest constitutes both a source of fodder and energy wood and an important support for grazing. The way of folks management (an average of 1 cattle, 19 sheep and 17 goats) is extensive. Sheep and goats stay about 10 months in the forest and move to the cultivated fields in summer.

For energy supply, wood is consumed daily, for heating in winter and for cooking bread all the year. The frequency of cutting the wood depends on the distance between the forest and home. When the supply is daily, the average by family is about 13.4 kg.

Two types of practices concern the cultivated areas.

-Some practices are inherited and persist namely on the plateau margins. They consist in traditional soil use, inside long and narrow plots, along the slope. Winter cereals dominate, replaced in some very small plots by spring grains, as corn and beans. Ploughing is manual and the fertilizers supply very rare. The income is very low and the stubbles grazed. The fallow fields occupy some rare surfaces and are grazed in winter and spring.

-Other practices are specific of the flat parts of the plateau, on the best soils, in plots which were occupied by the former colonisation or bought by urban owners. Irrigation is the first indicator of intensification. It is related to water pumped from the water table. The plots are wider and better maintained. Cultivation works are generally mechanised and fertilisation normally developed.

Due to the extension of cultivated lands on slopes, even on the steepest ones, the grazing areas outside the forest are very rare (less than 12% of the commune surface). But, nowadays, degraded soils by rills

and gullies, among the private fields, which were cultivated during a long period, seem to be abandoned and become a pasture area, but with very weak fodder possibilities.

Transformations

-The rhythm of transformation is quite low in the hilly parts, while it's much more rapid on the plateau, where new farms are continuously constituted in relation with the urban investment.

-There is not a unique trend. Some grazing areas are transformed into cultivated fields. And at the contrary, degraded cultivated fields are abandoned and become grazing lands.

-There is an important tendency to develop fences, both metallic ones, around the farms, or vegetative ones (use of cupressus trees in the modern farms, or cactus opuntia, more generally) and these fences play an important role in term of overland flow. In the fields with fences, intensified agriculture is now made with some irrigation and good soil management against runoff and erosion.

Existing practices on water resources

The main regional groundwater system sits in the Pliocene calcarenites (the Mamora aquifer). Due to the dipping of the Sehoul Plateau to the north, the calcarenites thin out in the south in the Sidi Azzouz plateau, and the volume of the aquifer is there, less important. For supply of water to farms and households, the inhabitants of the Sehoul commune are dependent on withdrawal of groundwater from artificial wells. The larger farms pump water from the Mamora aquifer, and some have deep wells to pump from the Miocene aquifer. However, the majority of farmers in the Sehoul Plateau, having traditional small farms, take water from a third, local groundwater system which consists of numerous small and unconnected water bodies concentrated in the alluvial terraces, confined below by the Miocene marls. The recharge of local groundwater systems depends solely on precipitation.

Of the water withdrawal, some is used for irrigation; the other part is for domestic use. In this region, the sustained availability of groundwater resources is vital. However, as a result of rising demands for withdrawal by the expansion of irrigated fields the renewable water resources per capita is declining.

The main water resouces are represented by the reservoir of the dam Sidi Mohamed ben Abdellah with a capacity of 433 Mm3 and which is expected to reach about 1.025Mm3 ; there is also a small dam Al Arjat Sghir with a capacity of 45000 m3 ; the water table has a potential of 8 Mm3/an.

The effective use of water in the commune concerns only the water table, while the SMBA reservoir is forbidden for the use by direct pumping (entirely devoted for the cities).

The irrigated farms represent about 790 ha, 3,6% of the commune cultivated surface. The system of drop to drop is generalised to the majority of exploitations. The farms are equipped with a well, a pump and a reservoir. Water is so, rationally used and welle conserved. According to the 2004 sensus, the families of the communes are not connected to the drinking water network. 72,9 % of the families use wells, 22,8% springs et 4,5 % public fountains

Existing uses of Forest resources (e.g. protection, production, recreational)

The forest occupies 30% of the Sehoul commune ; it is composed of cork oak and in its eastern part by *callitris articulata* and matorral (lentisque and oleaster) and some artificial plantations of pinus and eucalyptus. The forest has many uses. It is a main pasture land for the local population ; it is an important resource of fire wood and provides many other products. On the economic side, the forest is opened for exploitation of cork, of charcoal, and of eucalyptus wood. Cutting operations are organised by the forestry

administration and made by enterprises. The administration has also the duty of programmation of the forest management. Due to the proximity of Urban agglomerations, the forest is also visited for leisure. The orientation towards a touristic function can lead to a complete transformation of the management rules.

Strengths of existing land use practices

The existing agro-systems in the Sehoul region are mainly devoted to the production of food to maintain the reproduction of the units represented by the small farms. But to be able to maintain these systems, the farmers have to reduce as much as possible the factors of degradation, responsible of soil and fertility loss. The agro-systems associate grain production and mobile breeding in most of the exploitations. This system can be weakly efficient, but it has the advantage of many positive effects, on social and environmental terms.The economic income of this association grains/breeding is irregular. The annual production is less than 15q/ha and the income under severe climatic conditions of dryness is not able to maintain the equilibrium of the exploitations.

As the possibilities for diversification of the production are limited to some farmers and as the development of the breeding is exposed to risks, the adoption of other activities and emigration represent now the unique options for small farmers to respond to the scarcity of their income. The intensification of agriculture by plantation of fruit trees and the development of modern breeding are the options offered to the great farmers, with enough land, potential of irrigation and financial possibilities. This change remains marginal, as the surface where it occurs are relay limited. Agriculture and extensive breeding are two inter-dependent activities of the agro-system, which origine is very old before the 19th century. Their permanence is the expression of their social role, as the grain production feeds both humans and the animals; the animals contribute to maintain the soil fertility. The forest contributes to the alimentation of the animals.

The inequities in term of ownership are equilibrated by some common activities as the free breeding of animals. The current disappearance of some of these social practices explains the migration of the small owners. Their farms are given to other members of their family, or selled to urbans. In the big farms, the financial possibilities explain the introduction of innovations, as the rotation with beans and fodder, the drop by drop irrigation technique, the plantation of fruit trees. The irrigation, the permanent occupation of land and the generalisation of fences introduce constraints which make the free pastures disappear progressively, replaced by intensive breeding. This creates competition between the social categories.

The Sehoul environment is characterized by soil erosion and land degradation but this fact didn't orient the populations to implement special managements. Are they not conscientious of the risks? There are several approaches, like cultivations rotation, mobile breeding, ploughing along the contours which signify the will to restore soil fertility and reduce soil degradation. The recent project of agriculture development in the commune introduced two new techniques, the capture of runoff to feed the olive trees and the check dams on the big gullies.

Weaknesses of existing land use practices (e.g. unsustainable, uneconomic, causing degradation)?

The weak aspects of the existing land use practices are varied:

-The extensive cultivations continue to extend at the limits of the forest area by the farmers installed at the forest border,

-The extensive grazing is one of the practices which degrade rapidly the Sehoul ecosystem. The impact on forests is evident. The current pressure is about 2.2 sheet/ha, while the carrying capacity doesn't exceed 0.82.
-The weak use of fertilizers and of selected seeds explains the weak income with about 0.6 t/ha of wheat and 0.4t/ha of corn. Only the plots neighbour of houses beneficiate from an important supply of manure. The latter is more and more selled to the owners of the irrigated farms, who practice rich cultivations. In the plots devoted to cereals, chemical fertilizers are used, but with amounts which are not really adapted.
-The introduction of mechanisation is important for the modernisation of agriculture, but the form and the size of the plots are not adapted for the mechanical ploughing which is made along the slope and accelerates erosion.
L'effet négatif des pratiques culturales sur l'environnement est la conséquence d'une transformation des systèmes agricoles qui imposent de nouveaux rapports aux ressources en terres et en eau. C'est le cas notamment du recul de la jachère, de la pression sur les ressources en eau d'irrigation et de l'accès incontrôlé aux ressources forestières pastorales.

Some indicators of weakness
-The retreat of the fallow, in relation with the trend to the disappearance of the free breeding; the farmers must cultivate every year and have to reserve some plots to fodder production The fallow had the advantage to permit the restoration of the quality of the soil
-The animal load had the trend to increase on the land. Between 1997 and 2001 the number of cattle increased from 15000 to 17 000 (+ 11,7%), the number of sheep from 40.000 to 56.000 têtes (+ 28,6%).
-The pression on the water table, in relation with the extension of irrigation. In 2003, the supply to the water table is about 7,5 Mm3 in the context of an average of rain of 450 mm, while the withdrawal is estimated about 7,2 Mm3.
-The non controlled access to the forest and pastures
-L'accès incontrôlé aux ressources forestières pastorales ; the extension of fruit trees and of fences led to more stay of animals in the forest (about 300 days/ a year.

Major degradation issues due to the use of natural resources
In this region, according to the experimentation we made, the traditional land management systems - typically involving an equilibrate combination of agriculture, animal husbandry and forestry; under a weak human pressure - produce low amounts of overland flow and the lowest soil erosion rates. When the natural vegetation disappears, overland flow and the erosion of sediments are significantly enhanced.

Due to the increasing pressure, this region is undergoing major land use change. The tendency is for the replacement of natural traditional forest by exotic species (eucalyptus) ; the intensification of traditional land uses such as the reduction of fallow ; overgrazing in natural areas, despite the weak production of the vegetation and the poor quality of soils and their potentially high erodibility. The reduction of organic matter and vegetation cover results in soil compaction and higher overland flow generation in the overgrazed areas, whilst in the ploughed areas erosion yields are higher.

Heavily grazed and degraded shrublands, produce considerable amounts of overland flow, but no significant sediment and carbon loss at the small plot scale. Nevertheless, at a broader scale, the presence of rills in some fields and of gullies witnesses the erosional power of these high amounts of overland flow. At places, where the soil structure was disrupted (ploughed land), the erosion rates can be very high.

There is a fundamental role played by land use change in determining soil erosion hazard, through the changes on the soil and water processes. On the other hand, the soil biomass management (absence of manure supply and weak cover of the soils by vegetation) contributes to the low soil carbon content. Being a surface process, erosion displaces significant amounts of organic matter, which will decrease the carbon retention by the soils, inducing important soil degradation with severe implications on soil fertility and increasing the fragility of the surface.

The increasing pressure over this marginal area (due to the use of the better soils for commercial crops) leads to the use of steep slopes for poor agriculture purposes. This represents the highest risk for soil sustainability. The process of land degradation is more and more linked to the socio-economic evolutions and to the resources management. Grazing and Forests exploitation are still important, mixed with the extension of the cultivated areas. The overgrazing, over-exploitation of wood and the extension of agriculture on unfavourable lands, lead to extreme soil erosion and a dangerous silting of the dams' reservoirs.

The concentration of the population and flocks on weak slopes explains the retreat of the vegetation cover, the rapid soil degradation and the spreading of rills and gullies. The transformations of the rural context include the complexity of landownership (number of regulations, predominance of small holdership, scattering of fields due to heritage), and the urbanisation of high-quality agricultural land surrounding urban areas. In addition, the traditional small-holder agriculture is marginalised in favour of the modern, large-scale agriculture, whereas the latter is mostly responsible for the inefficient use of groundwater.

The deforestation and the extension of the cultivated area date from the early years of the 20th century and the limits of most of the forests were fixed in the years 1920-1930. But inside the forests and in the remnant pastures, internal degradation by overgrazing and wood gathering still continues. In the cultivated area the reduction of the surface and of the period in fallow, the mechanisation and plowing in the direction of the slope cause an ongoing land degradation due to the thinning of soils, crust formation and compaction. All these phenomena decrease the infiltration of rainfall, keeping back water from the soils that otherwise may be stored and percolate to the superficial water table. At the same time, the increasing runoff over the land surface causes soil erosion and the silting and pollution of the dammed lake, which play an important role in both water storage and the regulation of water provision in the dry season.

We can interprete the Earth surface evolution as follows:

- The surface covered by a dense forest represents a heritage where the soil is equilibrate, with a thin organic layer on top of a leached sandy horizon. This layer is permeable enough and well structured to absorb the total amount of rain, even during exceptional events.
- The density of population's increase during the 20th century, by natural growth, but also by immigration to this rural area, close to the cities of Rabat and Salé, led to the degradation of the forest. Two processes occurred; a process of overgrazing, with an over-use of the forest to feed the flocks during the dry periods; a process of cutting the wood for fire providing to the countrymen and for charcoal production to the cities.

-At the southern fringes of the Mamora forest, the increase of population was accompanied by the expansion of subsurban agriculture, in relation with the development of the neighbouring cities (production of grains, vegetables, fruits, breeding .....).

Inside the degraded forest, runoff occurs and erodes the organic horizon. The leached layer is exposed and can be removed easily by overland flow during heavy rain, or by wind[1] after a dry period, like what happened in spring 1995. In some places, small dunes are formed.

The current wind removal is not rapidly stabilized, even after a wet season. Grasses don't grow with a sufficient density, on the surfaces which lost already their organic superficial horizon. It's why, inside the forest, we have some bare perimeters, regularly removed in case of strong winds.

Measuring of overland flow and erosion on plots of 100m², in connexion with rain gauging; gave the following results:
The frequency of occurrence of an amount of runoff equal or superior to 0.1 mm differs according to land occupation.

-in the forests, the frequency is the lowest (10 to 27% of the total events), in relation with the vegetation density;

-under annual cultivation, the frequency is quite moderate (30 to 40%) if the soil is ploughed according to the contours;

-under a eucalyptus plantation, the erosive rains represent 45% of the events which means that this kind of vegetation releases a high overland flow;

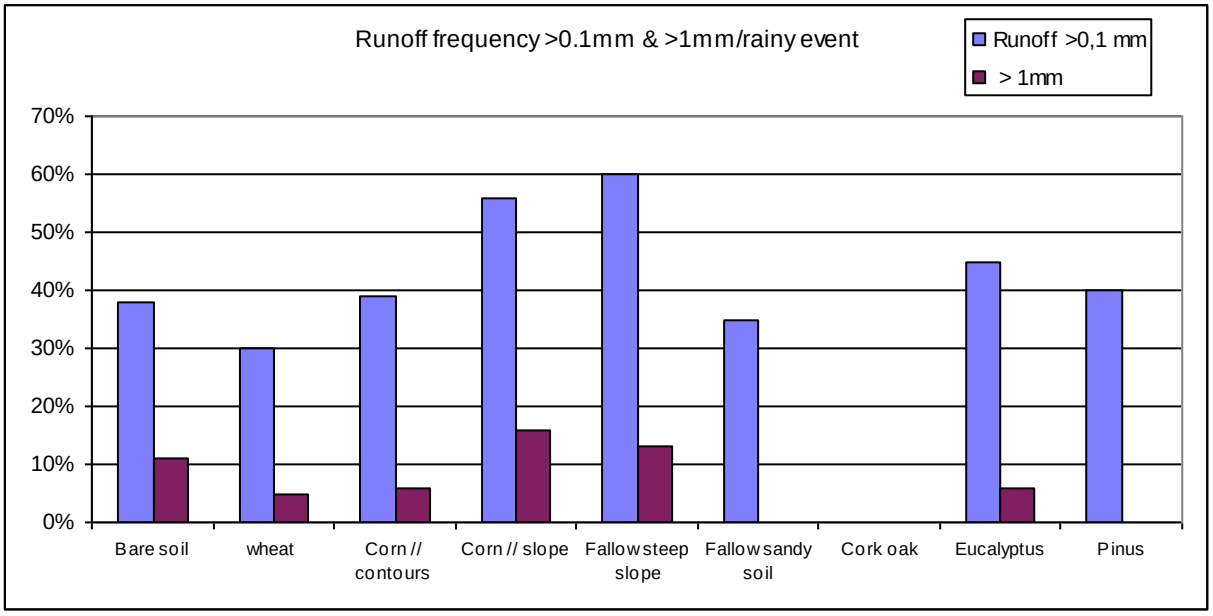
-the highest frequency is reached in the corn plots where the soil is ploughed according to the slope; this high runoff is in relation with the bare, deep and large furrows which have the behavior of real rills.

In the hilly parts of the commune, with gentle slopes, the runoff has not only an effect on soil degradation and on cultivation yield; a second effect is more dangerous in relation with the concentration of flow in the drainage network, through rills, gullies and streams. This functioning of the concentrated runoff is recorded in cases of important rains, when the superficial runoff reaches high values.

[1] Actually, this process represent the removal of an old eolian deposit which dates from the last glacial peak ; Dryness of this period explained the building of real dunes, made of the thick leached sands developed by pedogenesis during former wet periods. By Thermoluminescence, these dunes have been dated (26 to 20 Ka BP). This heritage of the late Pleistocence is evolving again, in the same way, but as a consequence of human impact on the forest.

50 to 70% of the high runoffs happen after some successive days of rain; in the plots maintained bare, 40% of the cases in which runoff overtaken 1 mm, have recorded more than 30 mm of rain in the days preceding the event.

If we compare the whole events of runoff, we have the following results. The corn, well implemented and the wheat cultivation, record a high runoff in only 6 and 3 % of the cases. We can conclude that the cultivated fields can offer normally a good protection, if the land is ploughed carefully and in the right way. The density of cultivation cover is important and barley or wheat constitute, in winter and spring, a good protection because they grow early and with a quite important density.



But these runoff results are only valid in normal or in dry years. The special events of continuous rain can lead to the saturation of the sandy horizon and produce an important overland flow. Under the continuous and intense rains, in the fields in fallow, the grass cover is enough to restrict the impact of the runoff events, while the recently ploughed areas record a very important erosion because the wheat is still, with a very weak density; on the bare surfaces, a rapid constitution of the crusts lead to the rapid and massive functioning of runoff.

The winter cereals constitute an enough protection for the soil; the bare plot records a relatively high rate of erosion, but it remains lower than what is recorded in the fields covered by corn in spring and ploughed many times during a cultivating season. The field ploughed according to the slope shows the highest rates. The eucalyptus plantation records very low rates, except after an operation of wood cutting.

The rain simulation permits to class the behaviour of fields, from the more generating runoff to the less one:

-the old fallow, on degraded and abandoned soil generates the most important runoff

-the recently ploughed field is in the second position, with a rapid destruction of the soil structure, crusting and functioning of rills on the fragile soil,

-the fields ploughed very soon in the first days of autumn, with a cereal cover

-the field cultivated the year before, not ploughed in autumn and let in fallow. In this field, the runoff and erosion are very weak.

Ploughing is an important factor of erosion; the comparison between ploughed fields and in fallow shows that under heavy rains of autumn, the ploughed fields record much more erosion than the in fallow ones. Even if the latter can show important overland flow; but water has not an important turbidity. This runoff with weak material transport on slopes can be positive and play another role in term of water availability for the dams. But it can also be dangerous downstream, and creates there forms of incision.

The fresh ploughed fields on slopes are then the most fragile areas. The differenciation is clear between fields recently ploughed just before the rain and with no cover and others where the cereals are already growed (ploughed very soon in autumn) and maintain more strongly the soil.

The technique used for ploughing plays also an important role and differentiates the fields ploughed along the contours and those ploughed according to the slope. The great danger is the monoculture of a whole slope ploughed and on which occurs an intense and continuous rain in autumn.

Synergy of mechanisms

Degraded soils record more runoff and soil erosion

Runoff and Erosion are responsible of soil degradation and reduction of infiltration and decrease of water storage in soils and in the water table.

Water resources degradation

Superficial groundwater resources in the semi-arid agricultural region east of Rabat (Morocco) are declining due to an increasing demand for consumption and irrigation and the limited use of water saving techniques. The recharge of the discontinuous superficial groundwater bodies is fully dependent on

infiltrating rain water. Soil degradation by overgrazing, crusting and an efficient drainage network enhance the rapid removal of rainfall excess water in surface runoff, especially in high-intensity rainfall events at the start of the growing season.

Institutional and political setting

• Existing institutions involved in natural resource management and desertification

Programme National de Lutte Contre la désertification (PANLCD) : Department of Forests and Department of Environment

• Existing laws and policies for land and water resource management (both customary and formal)?

Very complicated situation, with absence of integration between several generations of laws. In addition, the laws concerning forests and pastures concern two resources which have many uses and which are concerned by several local actors.

Water is under the dependance of the public sector. Their use is regulated by many laws, today integrated in the "Code de l'eau" (10/1995) which introduced some innovations in term of decentralisation and use.The property of land is private for most of it; only the forests are of a domanial property.

Relevant end-users / stakeholder groups (at all levels)

• Govt./Project staff

- National : The engineers and technicians responsible of the services of agriculture and forest.
- Local technicians of the same services

• Public administration

o agriculture and livestock: Provincial Direction of Agriculture "DPA"

o forestry : Regional Direction of Forests "DREF"

o water: Hydraulic basin Agency of the Bouregreg

o environment: no local representation

.The elected municipality council

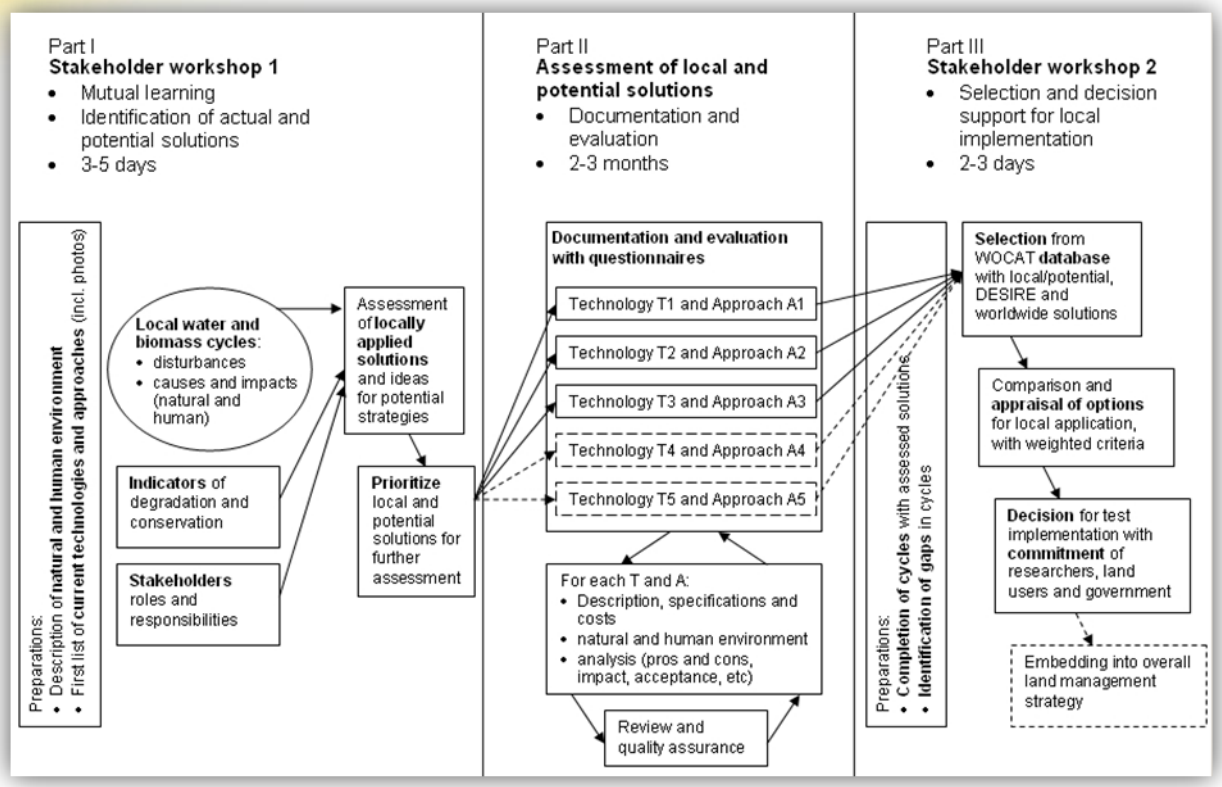
.The local power-administration of the commune,

• Research Centres and Universities: Mohammed V University and other scholls of engineers

• NGOs: more related to cultural activities, not really involved in development aspects.

• Land users : .Farmers with a high diversity of land use, and ownership

Workshops for researchers and stakeholders to select sustainable land management technologies



Researchers talked with local people and policy makers, and together they decided on the best options for sustainable land use. In the DESIRE Project the three Parts to WOCAT methodology were developed as outlined above. This provides decision support for choosing technologies suited to the local environment that includes social, cultural and economic factors as well as physical science.

In every DESIRE study site researchers and stakeholders held two workshops to arrive at their selection of approaches and technologies. At the first workshop stakeholders learned about how degradation happens, and how to avoid it.

Analysis of SLM technologies for controlling desertification

The main objective was to identify existing and new strategies, capable to prevent or mitigate land degradation and to experiment those strategies with some required techniques of measurement, in order to be able, after some years of experimentation to assure for these successful strategies a high and fast rate of dissemination among local stakeholders. The field work programmed for the monitoring of these techniques and approaches aims to determine their efficiency, in term of land degradation mitigation, social benefits and farm's yield increase.

In the Sehoul area, the main desertification problem consists in vegetation retreat, soil degradation, erosion extension and incision of channels at the expenses of former colluviums and alluviums

Priority remediation strategy as selected in the WB3 workshop is based on:

- intensification of breeding by the protection of grazing lands and the investment in the production of fodder

- keeping on the current system of cereal cultivation, but improvement of the land by fencing to reduce the animal pressure, reduced tillage and on the best situations, plantation of fruit trees.
  - This strategy was selected because it constitutes a continuation of the traditional way of life in the area
  - The additional criteria used to evaluate the strategies was the common agreement of both technicians and farmers

The choice was for implementing experiments in order
-restore the degraded pastures, namely those incised by badlands
-to improve the annual cultivations

a-Protection of pastures affected by gullies and rills, by fencing and the plantation of fodder shrubs (atriplex)

The objective is to demonstrate that the grazing areas can be more productive (with a higher biodiversity) and at the same time less eroded if the soil cover is protected and improved.

- -Follow-up of the surface and of the vegetation cover (the atriplex, the herbs, the soil surface) by comparison between the planted field and the other gullies
- -Micro-topographic monitoring of two gullies, one in the planted field and the other outside.

In September 2011, 2.5 years after plantation, the plot has obtained a really new landscape, compared to the fallows surrounding, even there where the gullies are not developed
Comparison between the behavior of 3 plots, 2010-11, the natural matorral, the eucalyptus plantation and the atriplex + fencing plot: The atriplex plot shows the best results in term of land cover by herbs, namely the permanent ones, and the less bare soil.

b-Fencing and minimum tillage

- Conservation, after harvest, of the crop residues in summer and autumn, before the first rains to reduce evaporation and the soil disturbance by animal grazing,

- the choice for minimum tillage to improve the soil on quite steep slopes devoted to annual cultivations

Description of the setup of the experimental trials with description of instrumentation if applicable

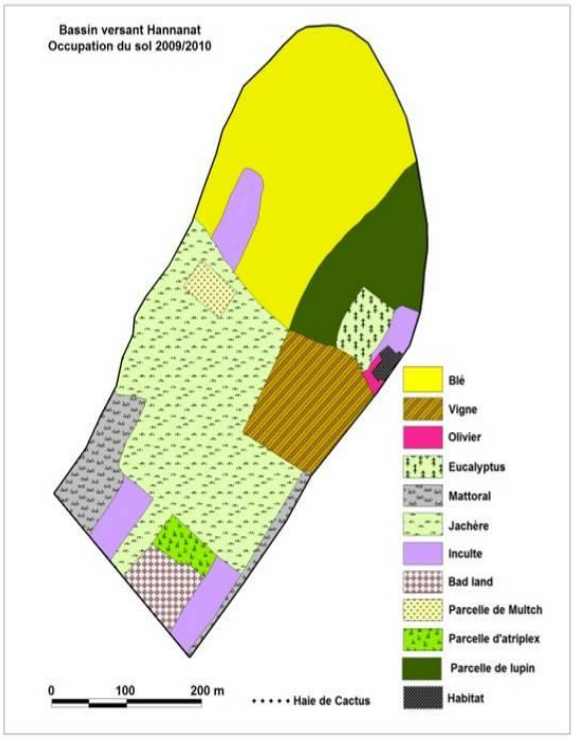
a- Protection of slopes affected by gullies and rills by the plantation of fodder trees as atriplex. The objective is to demonstrate that the grazing areas can be more productive (with a higher biodiversity) and at the same time less eroded if the soil cover is protected and improved.
Experimental plot of land of 5000m2, corresponding to an ancient fallow which became gullied. The plot of land was planted by atriplex halimus and put defense since April, 2009. The plantation was made in strips of 6m of distance with for objective stabilize ravines and restore the biodiversity. The density of the plantation is 760 plants / ha with a rate of 89,5 % success. The plot of land was irrigated every 20 days, the first summer.

We chose Atriplex halimus, because it is adapted to this environment of scrawny grounds. It is the fodder shrub which tolerates well the conditions of aridity of the ground and which can contribute to the valuation of the marginal and degraded grounds and to the improvement of the vegetable and animal productions in deprived regions. The plant possesses a system of roots very developed which allows it to use the water supply of the ground and to form a dense network retaining the soil.
- Plants of atriplex were brought from a tree nursery of the region of Bni Mellal
- digging of holes of plantation

- organized by a metallic fence
- plantation of shrubs
- irrigation in the pipe from a tank, every 20 days, in June, July and August
- the stake it defense is going to continue 2 years.

The monitoring concerned several parameters:
-the covering of the herbaceous vegetation, its biomass and the floristic biodiversity,
-evaluation of the fodder production : mineral part, organic part, fat, nitrogen matter, cellulose, and digestibility in vitro of the organic matter;
-soil state surface: soil moisture, resistance to penetration, cohesion, rate of pebbles on the surface and of the encrusted parts.
-Observations on the gullies transversal profile and on the steepness of the banks.

b- Conservation, after harvest, of the crop residues in summer and autumn, before the first rains to reduce evaporation and the soil disturbance by animal grazing, and the choice for minimum tillage to improve the soil on quite steep slopes devoted to annual cultivations.



Analysis and Results

Gullies treatment by plantation of Atriplex
The results of the monitoring during one year show that the Atriplex technique for correction of the gullies present several advantages:

- -Increase of the covering rate by herbaceous plants and of the degree of the soil protection; the rate of surface covered by herbaceous increases from 57% in the eroded fields to 87% in the planted plot, during spring.
- -Improvement of the quality of the herbaceous vegetation, with an increase of the permanent species, 3 times, after one year.
- -Improvement of the floristic biodiversity: in the Atriplex plot, the number of species is 2 times the one in the non protected slopes. The plot of land of atriplex put in defense contains the most

importing number of botanical species, that is 27 sort / m2 recorded in spring, 2010 against only 10 species / m2 at the plot of land in fallow

- -Increase of the vegetation biomass: the total palatable biomass has increased from 360 kg/ha to 1235, after management.
- -Improvement of the quality of fodder: the rate of nitrogen matter increased from 34 to 190 kg/ha and the rate of cellulose from 63 to 211 kg/ha.
- -Increase of the fodder production, from 127 fodder units per ha to 694, which represents a rate of 72%.
- -Improvement of the soil surface. In the atriplex plot is recorded a higher soil moisture than in the non protected slopes, and a weaker resistance to penetration as well as a lower cohesion.
- -The observations made during the intense episodes of rain of the winter 2010 show that in the atriplex plot more rain is infiltrated and less runoff is recorded. This process appears through the profiles of the gullies which already show lee steepness and more sharp banks.

The planted slope compared to the land in fallow on the other side of the basin

The soil management by atriplex plantation offers a good opportunity for both fodder production and soil conservation. The main factor responsible of this trend is the plot fencing during the phase of atriplex growing and herbaceous recovering. Less animal pressure on the vegetation cover and on the soil is then the solution for gullies cicatrisation and for ecosystem stability.
Less water will arrive downstream in the main channel, what will decrease the risks of dissection and the risks of mudding in the SMBA dam.

Cropping improvement by mulching and minimum tillage

The experimental practice was tested on 1 field of 500m², with the aim of a better management of the lands of annual cultures; it bases itself on two elements:

· the stake it defense against the excessive grazing (mulching)
· the improvement of the cultural technique (reduction of the works of the ground)

The objectives are:

- the restoration of grounds degraded by the monoculture.

- the ease of application of the technique, in a territory where the harness is often used in the cultures on slope.
- the wish to change system of breeding by opting for the abandonment of the free grazing and the adoption of an extensive breeding.
- The practice contributes in:
- restore the plant covering of grounds and their biological activity, in particular the microorganisms and the fauna of grounds.
- restore the quality of grounds in particular their structure and their capacity to store some water, thanks to the improvement of their surface state and thus by increasing their infiltrability.
- The experiment was the following:

Comparison of 3 plots of land:
1- A field grazed after harvest, monitored as a fallow plot, grazed in the year which follows.
2 – A field put there defense after harvest, cultivated in conventional plowing by the tractor, along the contour lines, in December, 2009;
3 – A 3rd field put there defense after harvest, with improvement of the cultural technique with reduction of the work of the ground, the application of a grass herbicide in December, 2009 + direct sowing by means of a seed drill with animal harness.
The essay was not decisive in year 2009-10, because the seed drill with harness does not bury enough seeds, because it acts on a very rocky ground; the passage on pebbles leaves a good part of seeds on the surface, what facilitated their consumption by migratory birds.
Nevertheless, the harvest was better in the portion of the direct sowing, not consumed by birds, compared with the result of the conventional plowing.


Herbicide in December


Direct seeding


A weak result in spring


A yield of about 5.4 qx/ha

Evaluation

The outcomes of discussion at the workshop:

- Why was these strategies selected? :

1- It becomes evident that the fruit trees, like olive trees represent a possible sustainable future for agriculture in many regions in Morocco
2- The grazing areas represent an important resource, if the land is better managed and the yield of fodder improved

- The economic criteria of yield and income, already used in the WB3 workshop was evaluated as more important than any others.
- The debate also raised the question of representative ness of the research led by the team, in particular the experiments. These concerning plots limited in extension and lasted only a reduced time. Besides the problem is to transfer what produces the research in the field of the application on the ground. The various offered alternatives are not quite practicable by the average developer and even less by the small farmers, what means the difficulty of scattering of experiments, even if they showed their abilities in the plots of some farmers.

The strategy of the farmers is influenced by the two main traditional activities, annual crops for food production and livestock for immediate income.

- -The farmers are more concerned by their immediate income than by sustainability and by the long term effects; it is then necessary to alleviate their level of conscience and at the same time make the remediation techniques profitable and have a real effect on their income.
- -The selected actions must be simple and easy to reproduce, in order to facilitate their gradual adoption by other farmers.
- -The coordination of Agriculture and Forests is a requirement, because of the very strong links between the 2 domains, state forest domain but on used in spite of the law and the private lands, used for the agricultural production and for grazing.
- -The choice for a better management of the cropped areas and the improve of the cover of the degraded pastures seems to be less costly and more immediately productive than deep changes in term of traditions
- -Incentives to land users are recommended to exclude grazing and to plant fodder shrubs in order to prevent soil erosion and stabilize gully formation
- -Bold political decisions are needed to reverse the trend and challenge of natural resource degradation and desertification.
- -It is also urgent to identify new legal contexts that can enable effective implementation of reforms and improvements.

Feedback from participants

Feedback from workshop participants – please include both a summary and where possible, illustrative quotes:

- The technicians and engineers adopted easily the methodology and were able to lead deep discussions and a real debate about the questions posed by the moderator, while the local farmers didn't appreciate the method of participation.
- The Engineers didn't appreciate a lot the research protocol and were suspicious with some of the results.

GULLY STABILISATION

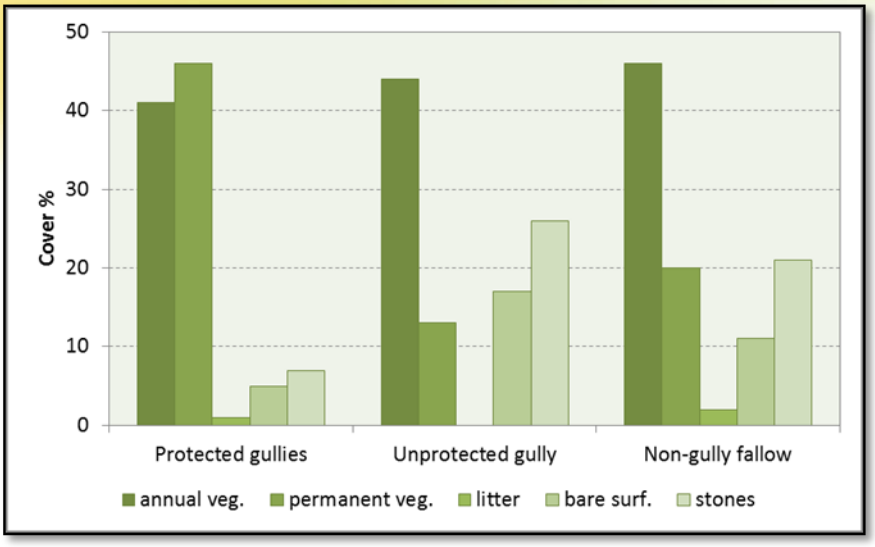
The North West of Morocco has areas with extensive gullying of the agricultural lands. High pressure agriculture and overgrazing, combined with occasional heavy rainfall, causes severe land degradation.
An additional problem is sedimentation in the drink water reservoirs downstream. For farmers in the area, annual crops for food production and livestock for immediate income is vital. Conservation measures must improve their situation or they will not be acceptable.

THE EXPERIMENT: PLANTING BUSHES TO STABILIZE GULLIES

A good way to stabilize gullies and prevent further erosion is planting shrubs. The species must be able to survive dry years, and *Atriplex halimus* was chosen and planted in 2009 in a regular pattern across the gullies. *Atriplex* is a Mediterranean species and adapted to the climate, but initially the plants were irrigated to protect them from drought. The gully area is fenced to keep out animals. The experimental plot has been isolated for two years after which controlled grazing took place. Apart from stabilization the species can be used as a fodder, and fencing of the area is expected to cause rangeland restoration.
This long term experiment was started in 2008 where weather conditions, biomass, soil moisture and soil properties are monitored.

RESULTS

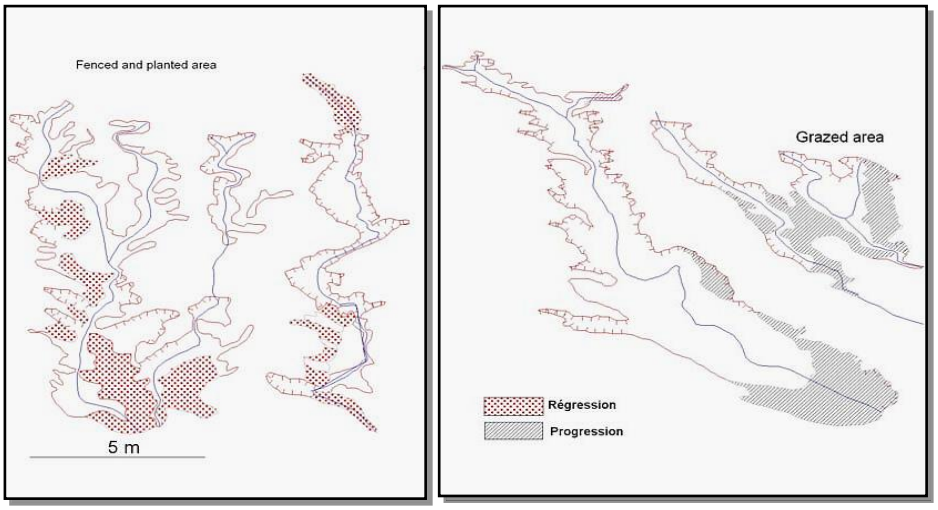
The experiment has clear effects both on the biomass increase and the gully stabilisation. Biomass of both annual grasses and perennials has increased considerably from 360 kg/ha to over 1200 kg/ha. Also the quality of the vegetation has increased, with good grass species, making this a viable source of fodder. The number of grass species was 20/m^2 on the 'atriplex' plot as opposed to 10/m^2 on the fallow plot. Expressed in cover % the cover was more permanent (see figure below). Experience shows that in a dry year the *Atriplex* survives and provides a minimum biomass, while in a wet year there is a combination of grasses and *Atriplex*. The effect on sediment loss needs longer monitoring at catchment level, but no forther gully change has been observed in the plot.



Cover % of the trhee plots: while the cover of annual grasses is about the same, the perennials give a good alround cover and protection.

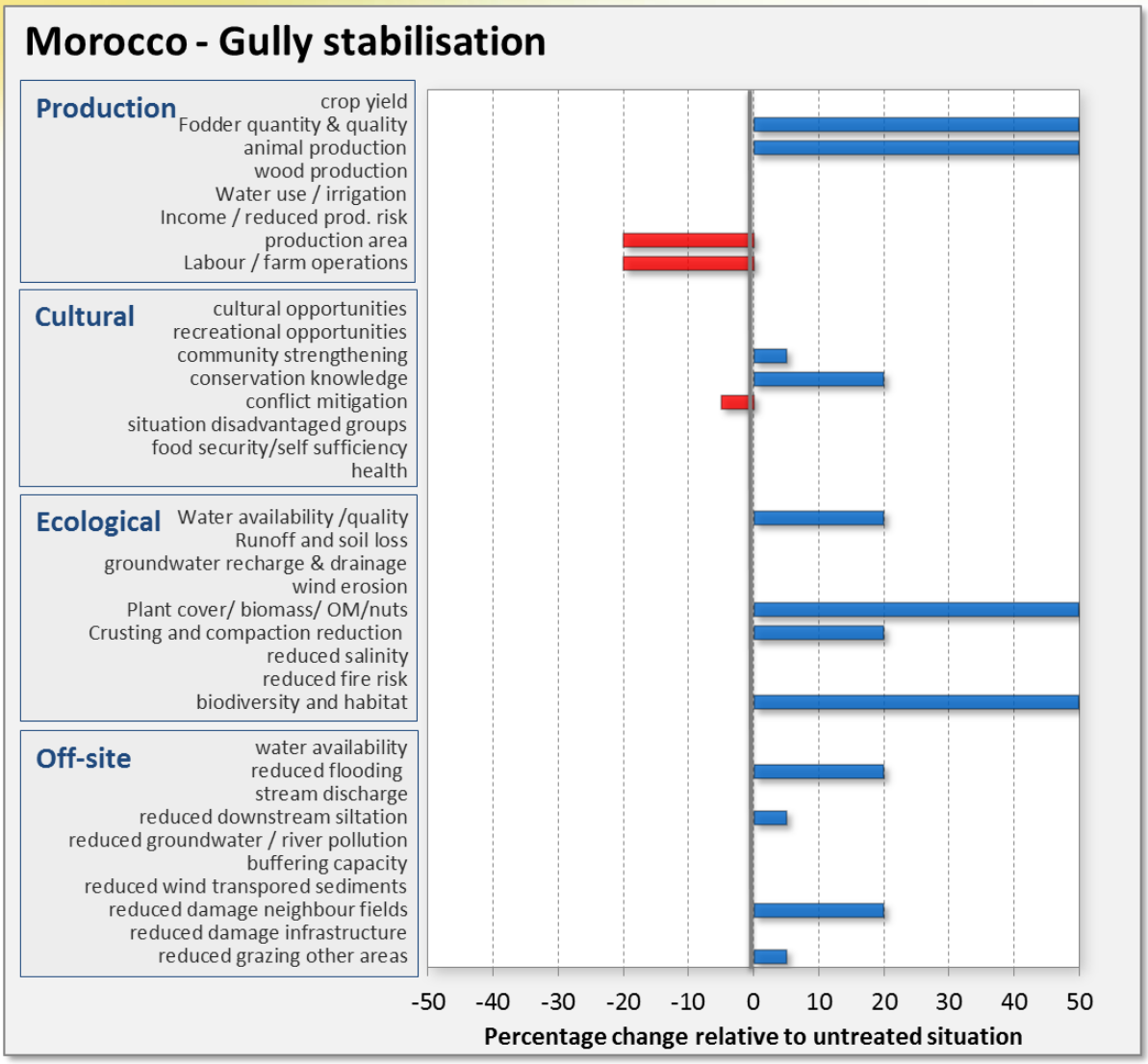
Soil moisture seems to be higher in the Atriplex plot although this may differ from season to season according to rainfall. The soil was less compacted in th plot. Effect on other factors such as soil organic matter need longer monitoring to evaluate. The establishment of this plot however also brings costs. An analysis of the costs and benefits in terms of fodder gives the following estimates. The prices are relative to currency changes.

The effect of 2 years of fencing showing a decrease of the gully area (left) by gradual collapsing and filling in (marked as regression) as opposed to the reference area (right) where the gully area that has increased (marked as progression).



HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

The results of the experiment are positively regarded. However the farmers point out that a large scale fencing and planting of the degraded lands in the region is impossible for them, without financial compensation for time and subsidized equipment and materials. An initial set aside period of 2-3 years would mean a substantial (temporary) loss of grazing land. The initial investments are approx. 2x as high as the combined 3 year returns in this experiment. The farmers are spectators at the moment, until the long term effects are clearer and more convincing. The general knowledge on land degradation is improving however, because of these experiments.

MINIMUM TILLAGE

The North West of Morocco is characterized by a strong variation in seasonal rainfall from year to year. Ploughing is done at the first rains after September and with sufficient rainfall there will be a moderate harvest in February (mostly Wheat and Barley). If the crop fails it is used for fodder. For farmers in the area, annual rainfed crops for food production and livestock for immediate income is vital. There are no additional water sources and water conservation measures could help in this situation.

THE EXPERIMENT: TERRACING AND COUNTOUR TILLAGES

Ploughing is a necessary tillage operation to open the soil and eliminate weeds. However it also destroys the natural soil structure that is more stable and it may cause excessive evaporation and compaction may result in runoff and erosion. The experiment compares a minimum tillage plot (left hand side) with conventional tillage to see if the water availability increases. Also a third plot was established: fallow with grazing (the normal practice). Additionally the minimum tillage plot was covered with natural mulch and residue. This should protect the soil from water and wind erosion and limit direct evaporation.

he soil is very stony and direct seeding was not possible, a seedbed was prepared with a shallow tillage operation. Also minimum tillage requires the application of herbicides for weed control. The first year light grazing was permitted; the second year the plot remained closed.

This 2 year experiment was started in 2009 where weather conditions, soil moisture and soil properties are monitored, as well as yield parameters. Several sets of TDRs were used for soil moisture monitoring at 5, 15 and 30 cm depth.

RESULTS

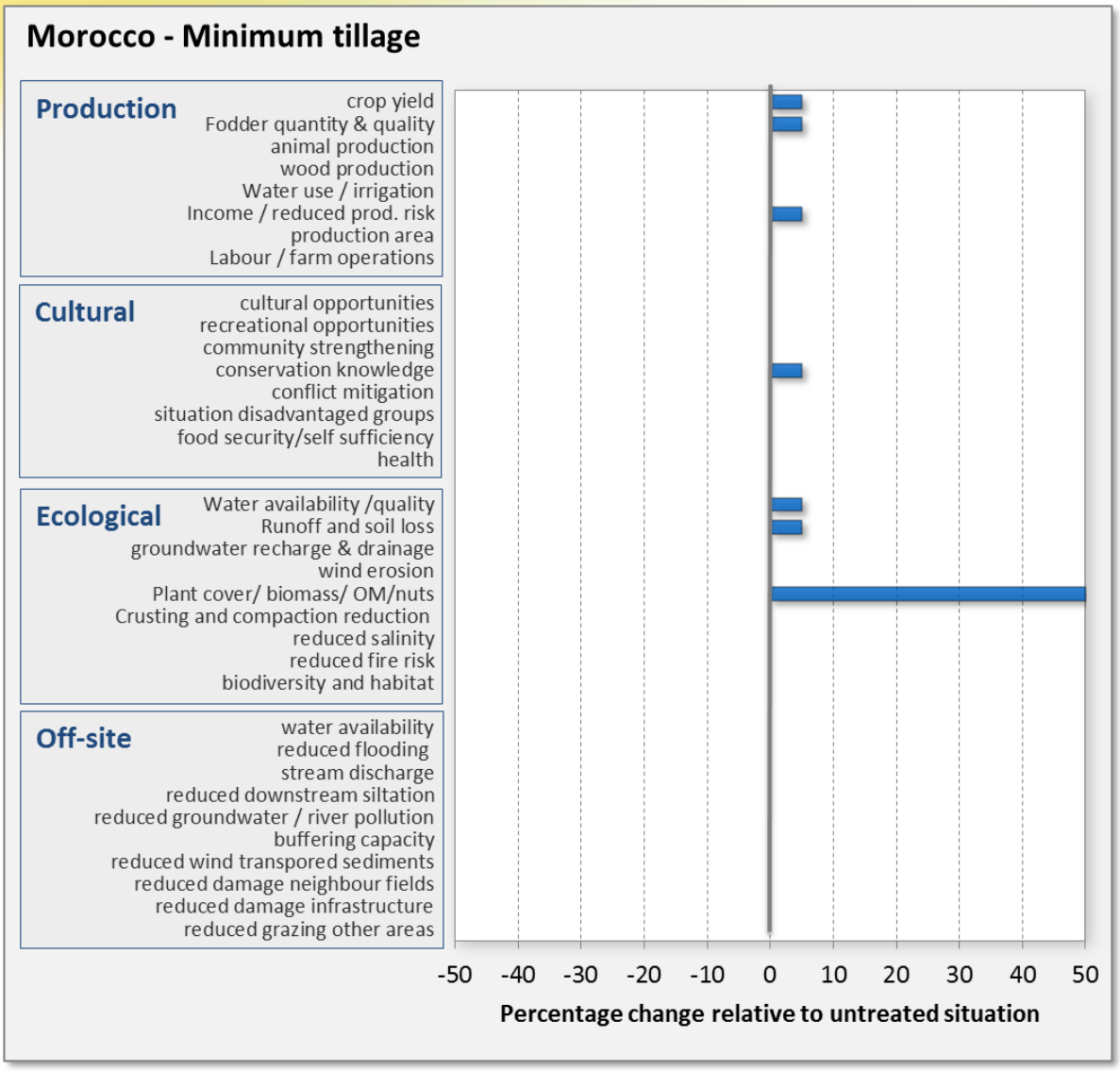
The experiment did not give clear results in water availability throughout the two year monitoring. In some periods the minimum tillage plot had more water, in some it has less than the fallow and normal tillage plots. The graphs below show the growing season from sep 2010 to april 2011, at 5 cm depth (top) and 30 cm depth (bottom).

The sensors near the surface show that the fallow plot is wettest (indicated with 'Jach') while the minimum and conventional tillage moisture contents are not significantly different (indicated resp. with 'LMA' and 'LC'). The moisture content at 30 cm depth is markedly higher for the Minimum Tillage (LMA) and similar for conventional tillage and grazed fallow. An explanation for this is in the effect of surface cover. The fencing and mulch caused a much higher vegetation density in the minimum tillage plot, causing more interception of rainwater and a dryer soil near the surface Possibly the mulch and cover caused interception of rainwater. This prevented in fact infiltration which takes place on the fallow plot, and so that becomes wetter. The treatment seems to work for the deeper soil, where the minimum tillage is wetter than the fallow and the conventional tillage (which is driest). It is however not clear if this is a result of fencing and vegetation, or of the tillage itself.

It is important to note that the soil on which the plot was established was not suited for minimum tillage. It is an old river deposit and very stony compared to other soil types in the region. The stoniness prevents the seeds from establishing properly which results in a loss of yield. Seeds are also more easily accesible to birds. Therefore some form of tillage is necessary in these circumstances. A different soil type with finer material may repond better to the measure.
A main effect may be the fencing, which prevents grazing pressure and gives therefore higher yield results. A slight increase in yield is recorded: 545 kg/ha of Barley on the minimum tillage plot compared to 505 kg/ha on the conventional plot. The amount of straw was 1230 kg/ha and 1100 kg/ha respectively.

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

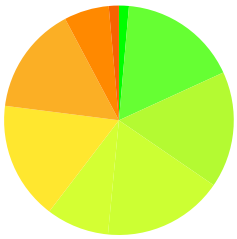
The farmers are not very convinced by the results. The small increase in grain yield and straw yield (used for fodder) was offset by the necessity for fencing in this experiment, which is seen as very negative. There is no visible improvement of the soil, and the location was not appropriate for minimum tillage because of the stoniness. Also there might not be sufficient material for mulch in this dry environment, which could increase pressure on natural areas for mulch production.

Baseline Scenario - PESERA baseline run

The baseline scenario shows that soil erosion risk is highest on the steep hillslopes along the rivers that dissect or limit the area in a predominantly northwest-southeast direction. The plateaus, for the larger part forested, stand out as low erosion areas. Biomass production correlates with land use, with highest

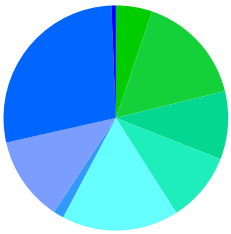
values for forest areas and lowest values for arable land. For forests, the biomass is relatively low due to high amount of grazing. For arable land, the areas with steep slopes and shallow soils are much less productive than alluvial areas.

Soil erosion



ion

Biomass production



uction

Technology Scenario:

Protection of pastures affected by gullies and rills, by fencing and the plantation of fodder shrubs (Atriplex)

- The investment costs for atriplex plantation amount to 28,020 MAD/ha (€2480)
- Full biomass increase is assumed to be achieved after 20 years; a linear growth trend is assumed.
- Grazing is assumed in without case. Apart from differences in fodder production, fodder quality is assessed by a conversion factor of 35% (without case) and 56% (technology) of fodder units to biomass.
- Price of fodder is 2.16 MAD/fodder unit (€0.19)
- Cost of fodder collection and feeding is assumed to be equal to herding animals
- A discount rate of 10% is applied

Applicability

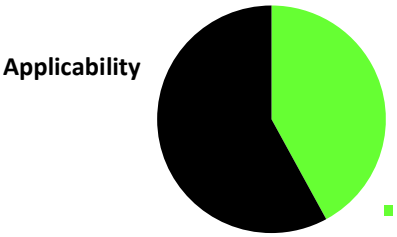
The technology is applicable on extensive grazing land and bare land. It can also be applied on steep cropland prone to gullying. All cropland above 20% slope is assumed to fall in this category. Although the technology is projected to lead to a very strong increase in biomass, this is likely a slow process, particularly on degraded lands for which the technology is intended. An investment for a time horizon of 10 years leads - under the assumptions made - to negative net present value. In the longer term, i.e. 20 years, the technology is highly profitable. Some effects are not taken into account, e.g.:

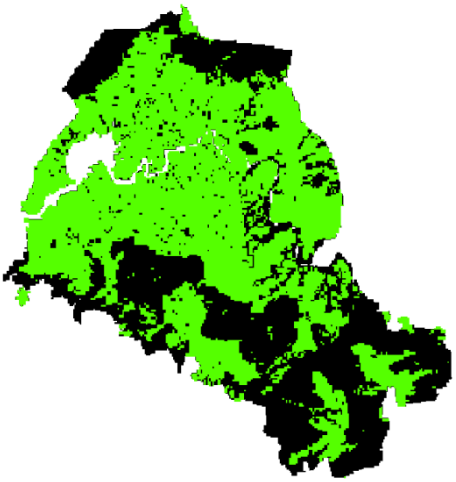
- Adoption of the technology reduces need for stubble and forest grazing, and productivity of cropland and forest may go up as a consequence.
- Off-site effects, such as avoiding the development of gullies in adjacent farmland and reduced sedimentation in the river network.
- Costs of implementing the technology may have an element of spatial variability (distance to markets for inputs, water source for irrigation and opportunity cost of labour for livestock grazing)
- The scale of application (e.g. fencing costs per unit area can be much reduced by closing contiguous larger areas – for instance by 50% for 4 ha and by 75% for 16 ha).

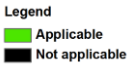
Technology Scenario: Mulching (fencing) and cultivation techniques (conventional tillage - or direct seeding)

Applicability

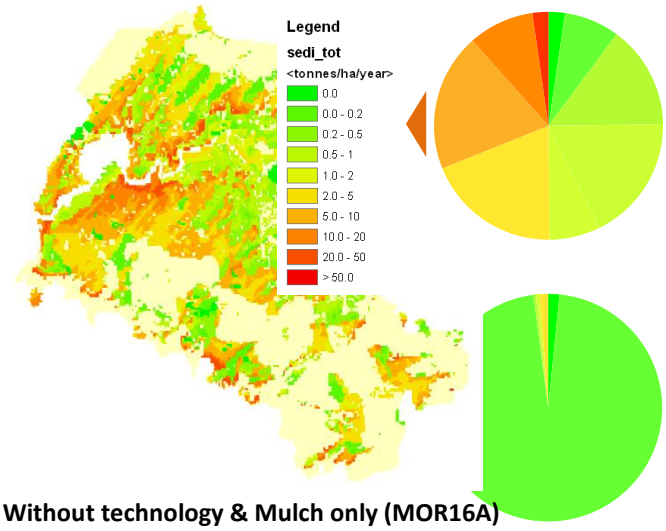
- The technology is applicable on arable land.



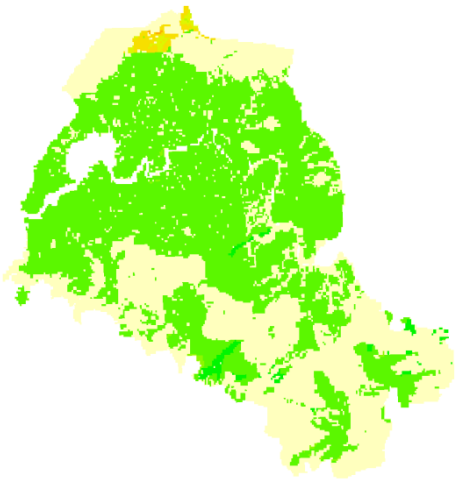




Biophysical impact: soil erosion



Without technology & Mulch only (MOR16A)



Mulch with direct seeding (MOR16B)

The important upfront fencing costs are not justified in the case of mulch only as the technology leads to only very modest (<10%) biomass increase. Moreover, no erosion reduction results (fallow period dry). In the case of direct seeding, erosion rates and biomass respond impressively. Economic viability is more mixed due to high operational costs of direct seeding but profitable in 81% of the applicable area.

Policy Scenario: Subsidising the protection of pastures affected by gullies

At a time horizon of 10 years, fencing and planting atriplex is not profitable. Land users are unlikely to wait longer for benefits to accrue. Hence costs of the technology need to be reduced. This is possible through a subsidy and/or coordinating the scale of implementation which will reduce per area unit cost. A subsidy could be part of a payment for ecosystem services scheme as stabilization of areas affected by gullies and rills has important off-site effects, e.g. reduction of sedimentation of the reservoirs in the study area, and relieving pressure on state forests. In this scenario a cost reduction equal to 50% of the investment costs is explored.

Policy Scenario: Prohibiting livestock stubble grazing

The need for fencing makes the application of mulching (with conventional tillage or direct seeding) difficult. Fencing implies a need for upfront investment – the resources for which may not be readily available. Moreover, land users might consider it a risky investment as they are unsure if costs can be recouped and when this will happen. This scenario explores the changes in economic viability of the mulching technologies if fencing would not be required. This could be the case if animals can be kept of the land, e.g. through policy enforcement.

Adoption Scenario: Fencing and Atriplex, Mulching and Mulching with direct seeding

An adoption scenario considers the simulated technologies (if more than one) in conjunction and assumes that the most profitable option has the highest potential for uptake by land users. In order to make the net present value of different options comparable, the same time horizon is applied to the analysis. For Sehoul, fencing and atriplex plantation, applicable on degraded land, and the two mulching variants (conventional tillage and direct seeding) for arable land are considered.

Conclusions

On a small scale the experiments are successful. The area is degraded in places but apparently a natural restoration seems possible when the areas are protected from grazing, at least temporarily. There are indications of a decrease in erosion while at the same time the fodder quality and quantity increases. Thus it can be beneficial for farmers. On the long run a further stabilization of the slopes is expected.
This positive effect is off-set by a large initial investment in time, labour and money. This would make a large scale adaptation of this measure impossible, and fencing areas that are otherwise open for grazing may have also social and cultural implications. Also initially the area is set aside causing a decrease of grazing land of a few years. A viable approach could be to establish several of these experiments in strategic and visible locations both to combat erosion and to promote acceptance and increase understanding.

A long term effect of a larger availability of fodder might be that a reduction in pressure on other ecosystems, such as the forested areas that are now overgrazed.

The fencing experiment does not give clear results yet (although 2 years is short for a natural soil structure to re-establish). The increase in yield may be a result of the fencing, decreasing the grazing pressure. Also, minimum tillage as a conservation measure was not correct for this soil type: the stoniness hinders proper seed establishment. On a different soil type (also present in the area) the results might be better. As a positive effect a clear increase in water availability, especially deeper in the soil and later in the season, is observed.

There are strong cultural objectives against fencing (apart from the costs). Traditionally there is free range grazing as a strategy for survival. At the same time there is an increasing tendency of fencing in the region to confirm ownership. It is clear that Large scale application of minimum tillage would mean a complete revision of farm management, with controlled grazing (with or without fencing), harvest of fodder instead of grazing of stubble, etc. It is difficult to estimate the effects. The negative pressure on natural areas (forests) may actually increase when animals are excluded from some areas, while the better managed areas show a positive ecological effect(less runoff, better soils etc). In any case it is clear that a large scale management change has influences beyond the immediate change in tillage, and there must be a strong economic incentive before such changes would take place.

- Baseline simulations show a mixed picture of soil erosion in the Sehoul area: about half of the area has soil erosion rates below 1 ton/ha/yr, but over 20% has rates of more than 10 ton/ha/yr.
- Improved crop rotations for cereals and improved rangelands with control of gullies were prioritised by scientists and local stakeholders to control soil erosion, soil fertility depletion and vegetation decline. Two concrete technologies were tested: protection of pastures affected by gullies and rills (MOR15) and mulching (fencing) of arable land (MOR16A/B). The technology scenarios show that both technologies can drastically reduce erosion rates. However, for mulching this only applies in combination with direct seeding (MOR16B) – mulching with conventional tillage (MOR16A) is ineffective in PESERA simulations. Atriplex planting on degraded land is according to model output capable of leading to 10-fold increase in biomass production. The time scale over which this occurs would need to be assessed, but experimental results were encouraging. A doubling of biomass production is obtainable in cereals under mulching and direct seeding, but only marginal improvements (<10%) are simulated for mulching and conventional tillage. Experimental results showed issues with direct seeding, and the divergence between both variants was not clear cut. Due to high initial cost of fencing, the tested technologies are only in the long term (> 10 years) profitable. Mulching with direct seeding performs best and is simulated to be profitable in 81% of the applicable area over a 10-year planning horizon.
- In the workshop to evaluate monitoring and modelling results, stakeholders downgraded the mulching technology based on inconclusive experimental results. This might also be due to the perception that cereal farming is not profitable, and needs to be diversified with leguminous crops and tree species. On the other hand, management measures that can be adopted without the need for profound changes in cultural practices were suggested to have better adoption prospects. Incentives and 'bold political decisions' were deemed necessary to exclude grazing and reverse degradation trends.
- A policy scenario reducing fencing costs by 50% made atriplex planting profitable in 91% of the applicable area. Such a subsidy would reduce soil erosion by on average 3.4 ton/ha/yr, at a cost of 4,306 MAD/ton (€273). Given that the zones where the technology would be implemented are riparian areas surrounding waterways and reservoirs, there could be important off-side benefits. For mulching, a policy scenario considered the effect of regulations to keep animals off the land – which would

remove the need for fencing. An additional 12% of the applicable area would see mulching and direct seeding become profitable, but with limited further decrease of soil erosion problems. Throughout the applicable area, productivity (and profitability) would increase. The combination of mulch and conventional tillage is too ineffective to become profitable. Importantly, the implications of such changes for livestock keeping must be clearly understood. As expressed in the workshop, the land users' priorities lie with their livestock and there is reluctance to change grazing systems.

- The adoption scenario summarises the above: the technologies tested are together applicable in about halve of the study area (woodlands being excluded). Without policies, only mulch with direct seeding offers scope for adoption, in about a third of the area. Considering the policy scenarios separately for each technology, roughly 15% of the area could be additionally made attractive to technology implementation.
- The global scenarios show that the technology can achieve very significant yield increases and erosion reductions in the vast majority of the applicability area. The investment costs to achieve this are relatively low, at €243/ton grain and €50/ton soil conserved. Per area unit, investment costs are nevertheless substantial. The modelling results need further experimentation to support claims of the effectiveness of direct seeding in particular.
- Planting atriplex and mulching and direct seeding are in principle robust land degradation mitigation strategies. However, fencing of determined areas might lead to overgrazing elsewhere; a holistic natural resource management approach is necessary to balance human and ecosystem needs. Planted on degraded land, atriplex can reclaim areas that have become unproductive. The mulching systems need further testing to identify risks and establish best practice.

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See: http://www.desire-his.eu/en/sehoul-morocco for full details of DESIRE research